

Feasibility Study: Economic Modeling of Microgrids

07/31/2015

Dean Weng, Project Engineer, EPRI

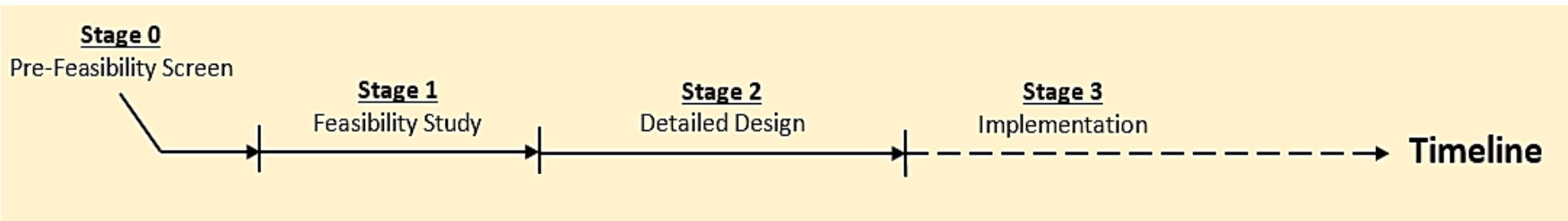
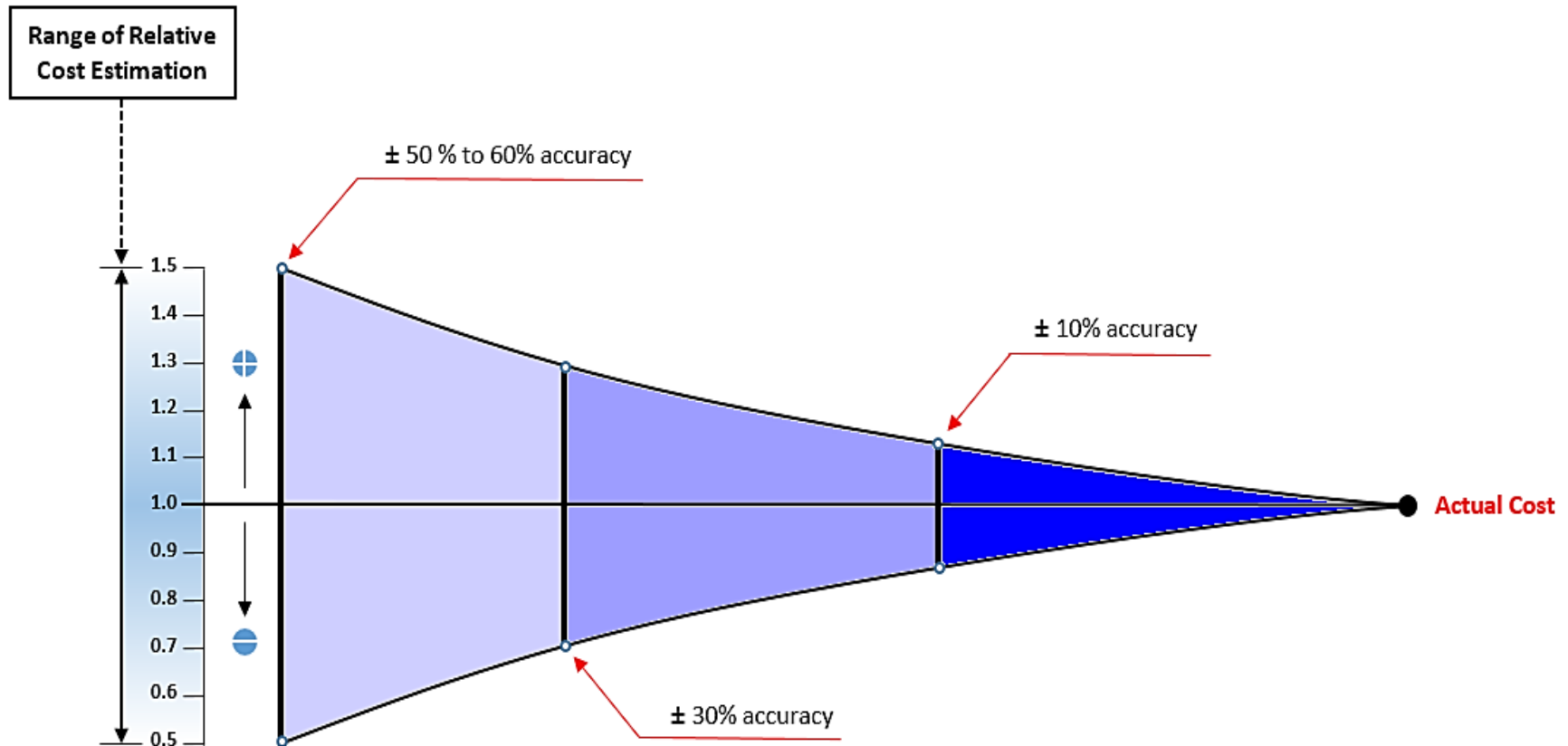
Arindam Maitra, Technical Executive, EPRI



Outline

1. Overview: Feasibility Studies
2. Utility Microgrid Sites, Types
3. DER-CAM Modeling Tool
4. Approach to Modeling
5. Sample Case
6. EPRI and LBNL collaboration

Microgrid Technical Design Costs and Evaluations



Phase I: Feasibility Study

1. Stakeholder Engagement

2. Define Microgrid Objectives

3. Site Survey & Data Gathering

4. Modeling & Simulation

5. Cost/Benefit Analysis

Utility Participants and Candidate Target Sites

DOE Project Participants (Level 1)

Supplemental

1. Ameren
2. Central Hudson
3. National Grid
4. United Illuminating
5. Entergy
6. Southern Company
7. TVA
8. EDF
9. Xcel
10. Northeast Utilities
11. Excelon
12. We Energies
13. E.ON
14. SRP

Feasibility Studies (Level 2)

Supplemental

1. United Illuminating (*Bridgeport, CT*)
2. National Grid (*Buffalo Niagara Medical Campus, NY*)
3. Entergy (*Medical Corridor in MS*)
4. EDF (*Concept Grid*)
5. TVA (*Cheeroke Farms*)
6. Peco (*Navy Yard, + 1 site TBD*)
7. We Energies (*Century Park*)

Design Analysis (Supplemental)

1. National Grid
2. ConEd
3. SCE
4. We Energies

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

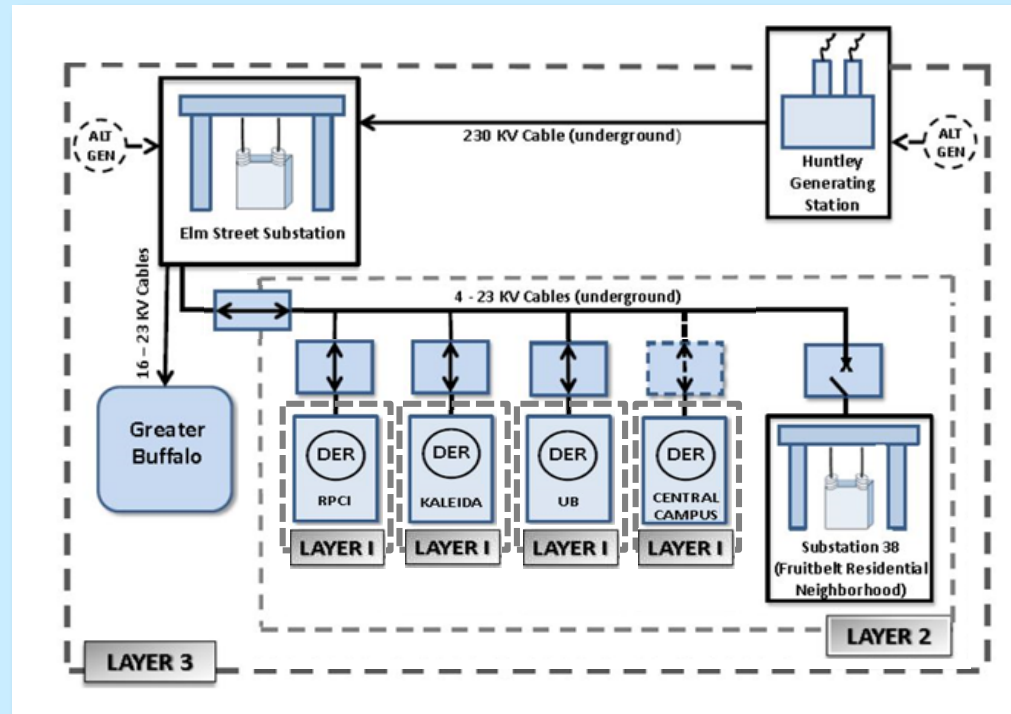
TVA

Cherokee Farm

United Illuminated

Bridgeport

Buffalo Niagara Medical Campus



- Multi-layer microgrid concept
- Many critical health and research services
- CHP likely to be attractive (thermal study being conducted)

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

TVA

Cherokee Farm

United Illuminated

Bridgeport

University of Mississippi Medical Center



- Critical health services, medical schools, research, police
- Cooling centric - a host of centralized chillers serve the campus
- Loss of power would force evacuations during the summer

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

TVA

Cherokee Farm

United Illuminated

Bridgeport

Cherokee Farm Innovation Campus



- Green field project
- Business park, UT research centers, hotel, hospital
- DER test bed – solar PV, batteries, fuel cell, CHP, EV

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

TVA

Cherokee Farm

United Illuminated

Bridgeport

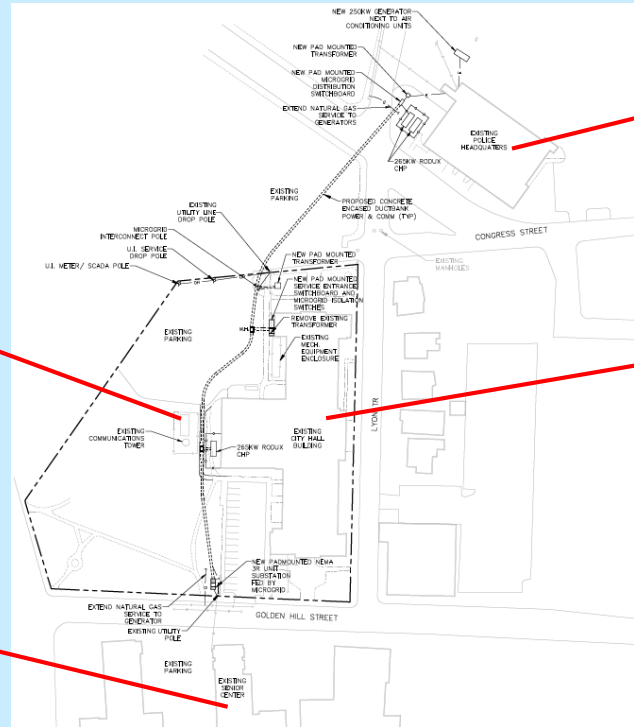
Town of Bridgeport

**Communications
Tower**

**Senior
Center**

Police

City Hall

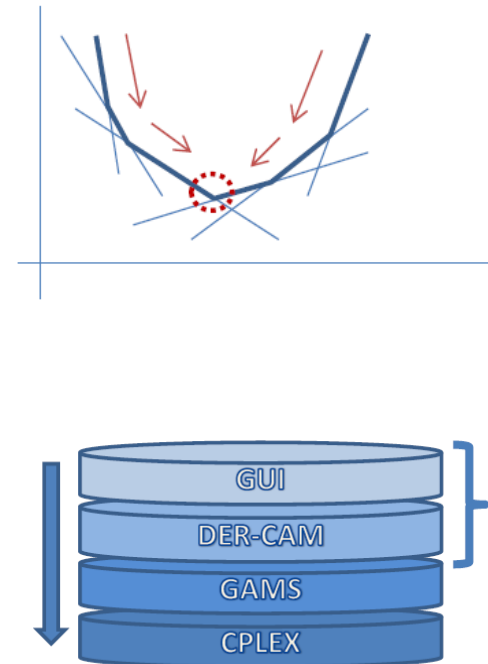


- Brown field project
- Resiliency for emergency services
- Part of a Connecticut D.E.E.P. initiative

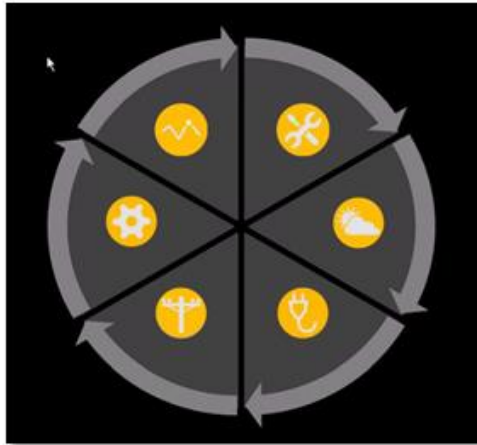
DER-CAM Modeling Tool

Distributed Energy Resources Customer Adoption Model

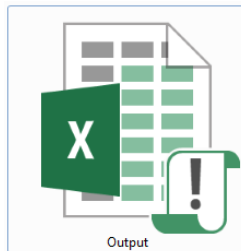
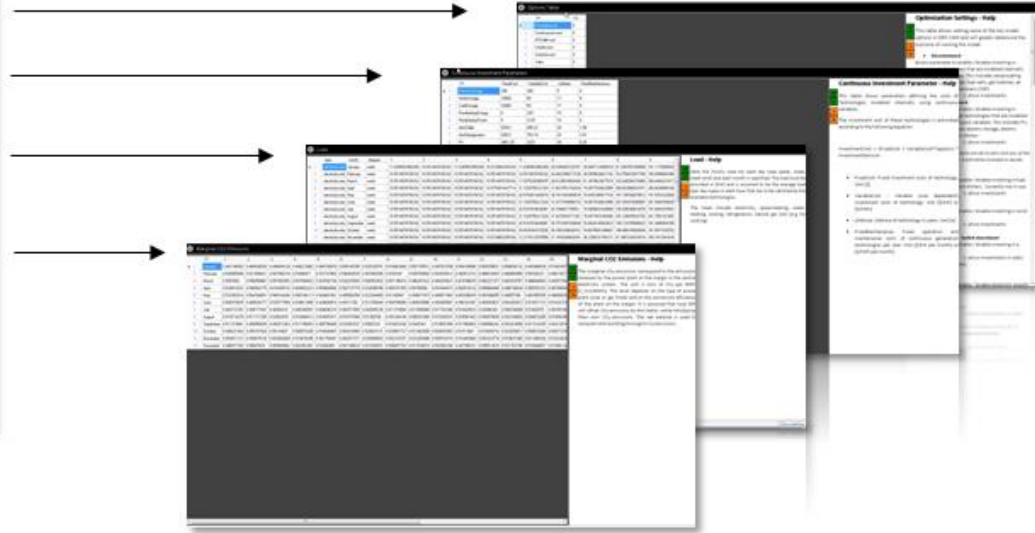
- Developed at Lawrence Berkeley National Lab
- Energy system design using Investment & Planning (I&P) version
- Economic optimization model
 - Objective function
 - Constraints
- Mixed Integer Linear Formulation (MILP)
 - Decision variables can be integer or continuous
 - Objective function and constraints are linear
 - Global minimum is guaranteed
- Platform: GAMS w/ CPLEX



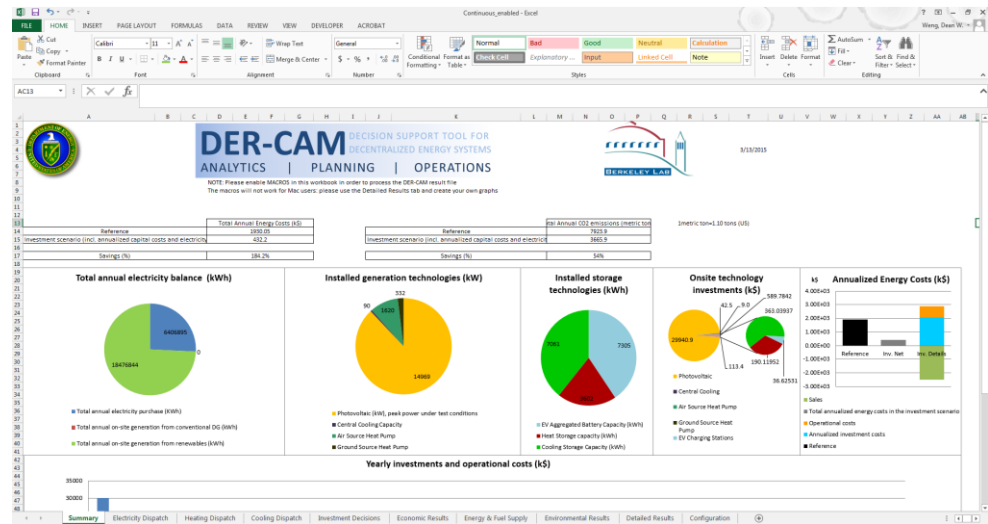
Interface



Remote Server Web Interface

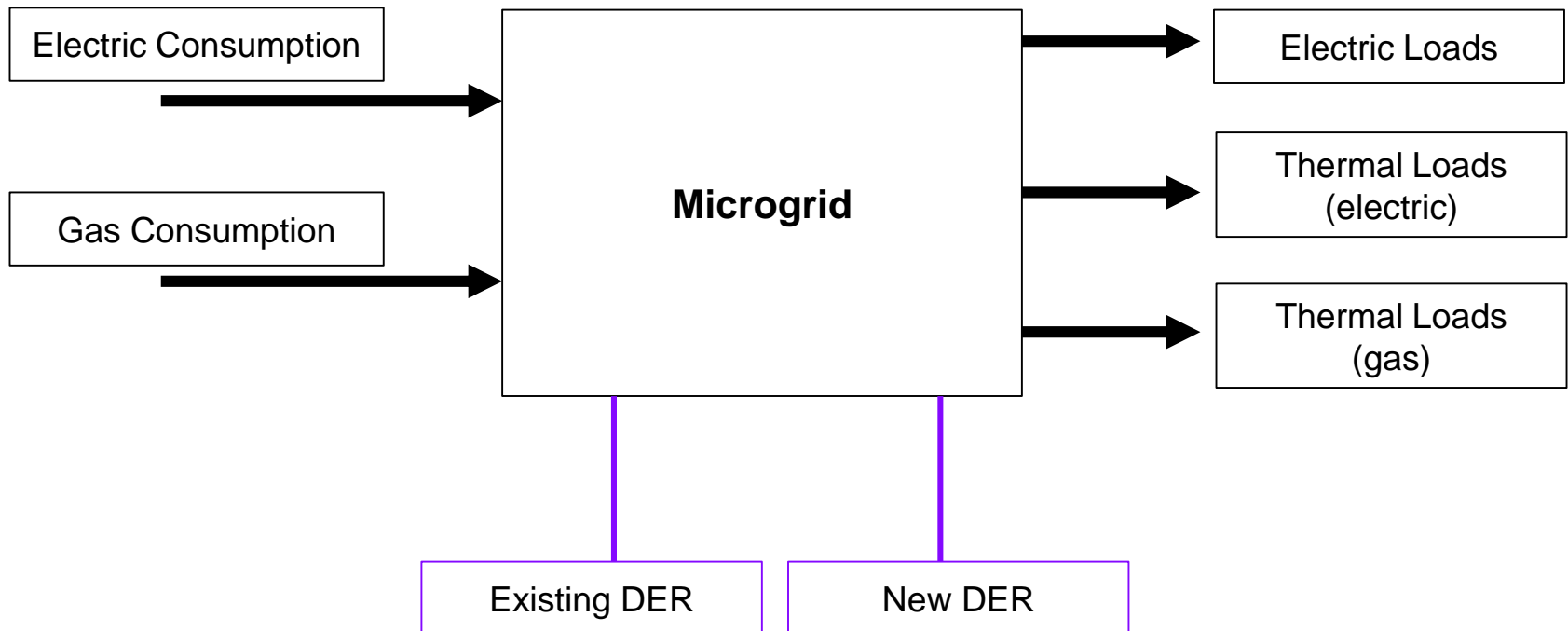


Output as an interactive excel macro



Modeling Approach

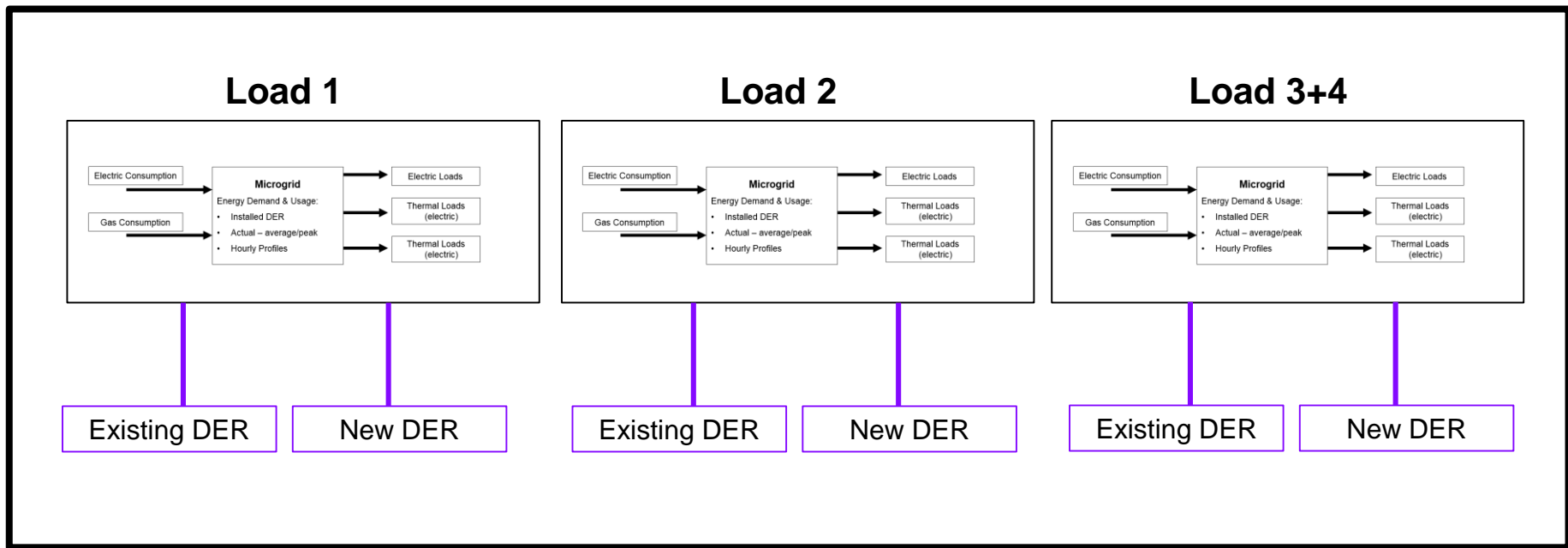
- “Black Box”
 - Simple energy-in, energy-out evaluation



Modeling Approach

■ Multi-black box approach

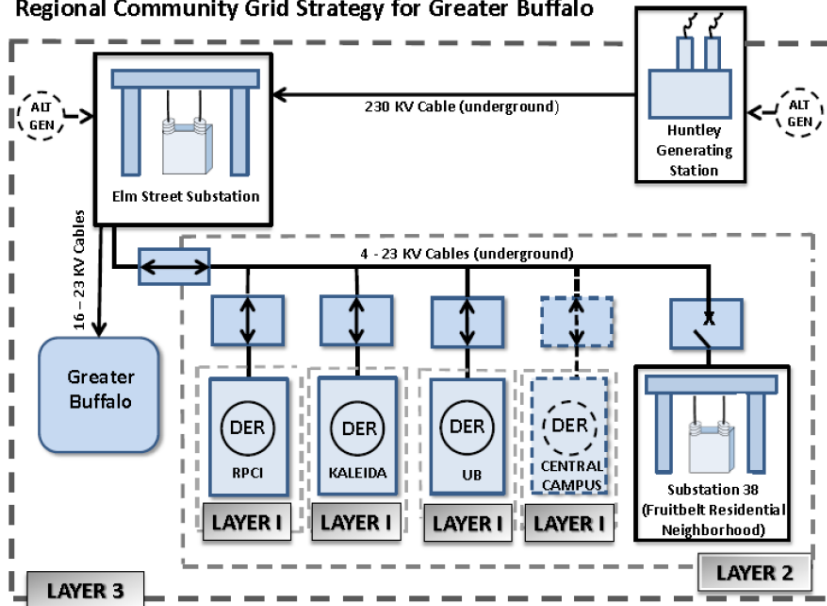
Microgrid



Modeling Approach

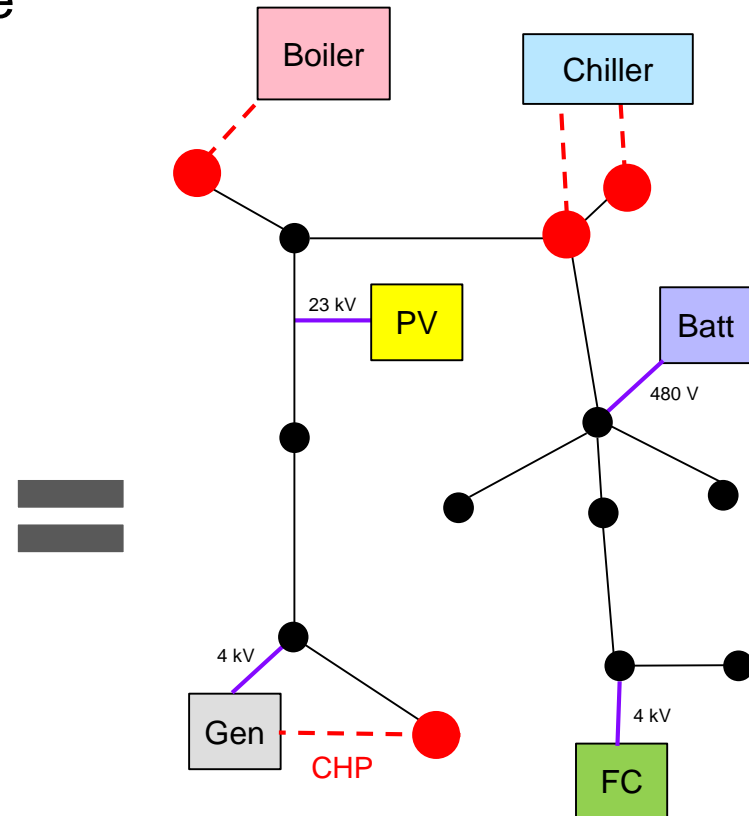
- Nodal network
 - Most accurate
 - Also most time and data intensive

Regional Community Grid Strategy for Greater Buffalo



System Information

- Network R and X impedances
- Load power factors
- Generator power factors
- Load locations



An Illustration

Modeling Tools

DER-CAM

Inputs

Electrical & Thermal Loads



Electricity & Gas tariff data







DER data



Site Weather Data






Objectives

-  Minimize Cost
-  Minimize Emissions
-  Renewable Penetration
-  Outage Duration

DER-CAM Optimization Engine

Constraints


-  Cost/Emissions Cap
-  Zero Net Energy
-  Force Fuel Cell

Outputs

 Optimal DER Mix & Capacity

 Optimal DER Dispatch

 Investment & Financing

 Quantitative Cost/Benefit

Modeling in DER-CAM

Sample Case

■ Basic data requirements:

Data Needed	Data Source
Electrical Load	Serving utility
Thermal Load	Serving utility
Electrical/Fuel tariffs	Serving utility(s)
DER technical specifications, price points	Market research, Manufacturers
Weather (irradiance, wind speed, temperature, etc.)	PVWatts, weather stations, EPRI

■ Customer information:

- Willingness to provide demand response (load shifting/curtailment)
- Value of Loss Load (VOLL)

■ Modeling objective

Modeling in DER-CAM

Sample Case (Cont.) – Background

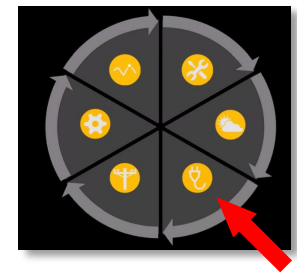
- Hospital
 - 5 floors
 - 241,351 (ft²) total area
- Location: Jackson, Mississippi
- Utilities: Entergy, Atom Energy
- Loads: electric, cooling (electric), heating (gas)
- Existing assets: grid, HVAC, boiler, diesel genset
- Objectives:
 - Cost minimization
 - 1 week outage duration
 - 100% load served
 - 10% renewable penetration



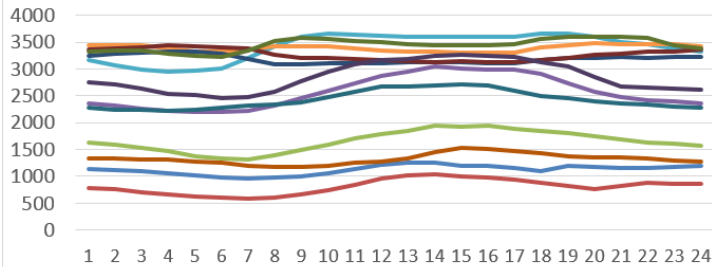
Modeling in DER-CAM

Sample Case (Cont.) - Loads

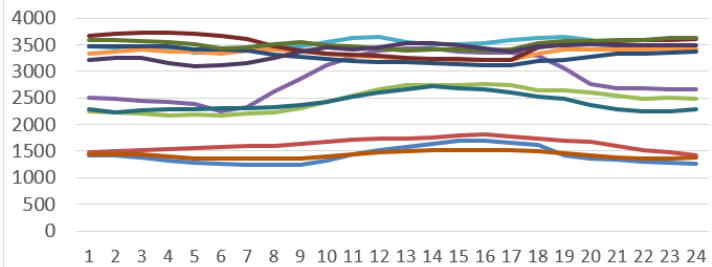
Loads



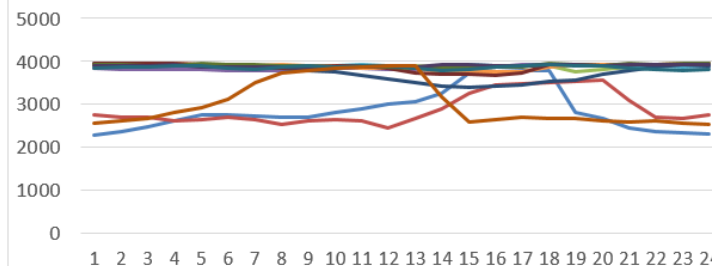
Week day loads



Weekend day loads



Peak day loads

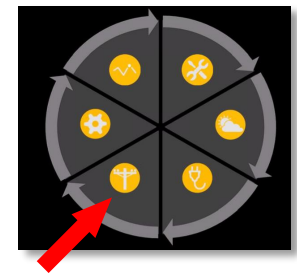


Data Processing

	type	month	daytype	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	electricity-only	January	week	5868.79	5859.22	5838.75	5790.42	6219.42	6192.38	7562.85	8347.6	8852.3	9044.06	9233.7	9354.48	9155.41	9347.76	9416.29	9291.18	9222.2	9115
2	electricity-only	January	week	5721.31	5700.8	5675.95	5657.39	6150.17	6162.76	7592.74	8374.04	8791.2	9025.95	9372.72	9468.59	9242.52	9402.15	9446.05	9200.53	9261.37	9096
3	electricity-only	March	week	6055.47	6047.43	6045.12	6046.57	6659.98	7701.39	8712.69	9374.96	9735.32	10075.23	10272.85	10332.64	10293.7	10302.74	10294.94	10291.44	10119.48	10057
4	electricity-only	April	week	7072.71	7023.19	6702.43	7286.49	7394.95	8602.29	9423.09	10009.32	10594.23	10906.93	11653.25	10991.05	11111.1	11138.2	10996.13	10654.06	10756.94	9296
5	electricity-only	May	week	7520.17	7695.42	7647.18	8235.89	8277.29	9634.41	10640.32	11212.77	11695.94	11862	11930.25	11622.07	11732.48	11709.71	11598.33	11631.8	11521.6	9962
6	electricity-only	June	week	7971.23	7965.51	7966.28	8474.85	8388.15	9810.61	10761.38	11224.16	11552.45	11590.11	11571.52	11247.84	11254.47	11347.25	11224.12	11249.52	11126.53	9727
7	electricity-only	July	week	7861.97	7853.88	7854.06	8311.43	8278.97	9542.64	10346.48	10637.21	10991.04	11038.76	11029.45	10769.09	10919.22	10924.44	10764.31	10745.95	10594.54	9717
8	electricity-only	August	week	8114.4	8137.12	8158.52	8707.67	8712.74	10085.1	10876.96	11123.06	11373.99	11398.42	11387.95	11078.87	11218.33	11206.95	11044.16	11112.37	10973.32	9444
9	electricity-only	September	week	7979.76	7968.15	7937.38	8394.14	8391.66	9735.25	10560.06	11052.45	11507.76	11541.71	11532.41	11238.8	11361.34	11362.48	11224.11	11232.29	11091.57	8665
10	electricity-only	October	week	7595.55	7598.22	7589.91	7952.32	7986.74	9259.14	10000.71	10451.14	10945.3	11125.5	11304.03	11027.64	11236.02	11389.2	11156.72	11067.44	10809.21	9423
11	electricity-only	November	week	6806.61	6764.03	6769.88	6914.67	7288.34	7643.72	8922.05	9503.46	10044.36	10319.11	10511.21	10576.25	10474.04	10663.9	10639.72	10579.32	10495.05	8992
12	electricity-only	December	week	5946.8	5803.49	5823.18	5822.34	6261.75	6275.42	7643.97	8448.27	8795.88	9160.67	9268.44	9343.44	9103.35	9243.76	9234.62	9095.24	9148.6	8996
13	electricity-only	January	peak	6103.67	6135.05	6234.88	6481.54	7282.45	7260.45	8885.58	9636.32	9896.26	10331.45	10111.04	10109.11	9860.4	10341.63	10801.07	10937.93	11028.91	1111
14	electricity-only	February	peak	5493.62	6406.78	6370.4	6195.6	6606.07	6612.3	8318.06	9234.11	9852.23	9856.63	9886.68	10081.71	9884.34	10429.73	10446.84	11042	11137.18	9111
15	electricity-only	March	peak	7400.05	7385.62	7346.07	7993.64	8033.37	9715.97	10591.46	10958.08	11010.38	11191.51	11206.29	11062.76	11326.02	11349.7	11362.42	11337.04	11229.25	1029
16	electricity-only	April	peak	7238.59	7197.74	7163.83	7458.39	7628.43	9586.24	10596.74	10873.46	11186.06	11310.02	11173.94	10911.66	11232.9	11249.31	11268.27	11246.26	11196.52	9707
17	electricity-only	May	peak	7337.38	7330.26	7293.07	7986.01	7977.09	9601.26	10591.48	10845.6	11030.9	11216.09	11324.26	11059.05	11324.42	11323.57	11333.34	11393.36	11489	9418
18	electricity-only	June	peak	7403.13	7388.17	7410.93	8110.67	8036.18	9661.97	10590.11	10995.79	11139.14	11223.78	11261.8	11089.96	11287.88	11198.4	11192.52	11215.26	11145.45	9165
19	electricity-only	July	peak	7409.77	7417.1	7402.19	8068.59	8059.74	9634.05	10561.38	10822.82	11031.18	11054.58	10974.11	10574.97	10761.95	11088.6	10702.69	10778.04	11064.45	8771
20	electricity-only	August	peak	7409.87	7420.96	7422.21	8112.66	8108.2	9752.44	10590.4	10849.38	11134.61	11218.75	11250.05	10880.9	11007.22	10988.31	10985.35	11030.64	11081.01	9198
21	electricity-only	September	peak	7414.07	7400.26	7363.31	8033.14	8091.54	9794.89	10596.32	10885.19	11116.51	11109.7	11142.45	10817.73	11087.54	11094.74	11070.09	11094.11	11175.13	9290
22	electricity-only	October	peak	7385.01	7360.58	7364.4	8040.46	8002.23	9741.66	10547.32	10818.76	11056.64	11141.84	11164.04	10883.14	11168.47	11246.03	11195.05	11198.76	11228.91	9331
23	electricity-only	November	peak	7405.47	7403	7382.73	7328.96	7960.37	8632.73	9833.14	10425.85	10837.46	11086.43	11170.25	11030.46	11076.64	11046.71	11016.76	11094.62	11111	9111
24	electricity-only	December	peak	6044.1	6045.38	6024.93	6077.36	6877.1	7100.42	8275.99	91038.12	10389.95	11027.46	11141.97	11171.02	10862.14	11020.69	10621.23	10564.47	10881.1	1003
25	electricity-only	January	weekend	4728.22	4716.97	4716.04	4722.52	5340.26	5315.25	6899.14	7643.15	7952.17	8175.04	8301.95	8386.86	8172.41	8414.61	8418.22	8422.93	8444.96	8443
26	electricity-only	February	weekend	4534.1	4500.97	4436.69	4362.66	4898.66	4877.91	6375.24	7084.15	7446.57	7730.67	7886.86	7971.71	7804.21	8149.84	8199.09	8214.06	8254.05	8256
27	electricity-only	March	weekend	5346.81	5338.94	5333.44	5819.51	5952.13	7082.46	8140.3	8644.38	8991.23	9144.51	9259.64	9138.78	9355.25	9537.93	9625.4	9717.76	9639.67	8153
28	electricity-only	April	weekend	5778.72	5712.63	5652.25	6263.74	6245.53	7672.3	8724.41	9103.72	9498.29	9712.66	9886.09	9722.95	10195.24	10339	10321.32	10344.74	10389.63	8747
29	electricity-only	May	weekend	6762.48	6812.25	6477.88	7022.62	7188.91	8653.23	9884.14	10306.42	10589.82	10749.46	10798.41	10897.14	10718.09	10754.86	10789.77	10774.33	10794	8847
30	electricity-only	June	weekend	6873.98	6915.98	6880.9	7483.43	7321.05	8954.52	9862.17	10242.56	10510.89	10615.92	10609.86	10327.05	10534.54	10899.24	10899.24	11067.19	11067.87	8546
31	electricity-only	July	weekend	6803.87	6889.53	6936.08	7574.95	7564.95	8982.45	9689.92	9859.64	10088.42	10161.08	10164.31	9895.07	10191.95	10197.98	10088.25	10180.59	10081.17	8260
32	electricity-only	August	weekend	6807.63	6820.37	6849.69	7558.78	7512.13	9140.52	10019.6	10322.16	10489.69	10590.53	10566.51	10229.11	10497.06	10434.78	10434.38	10473.29	10487.85	8405
33	electricity-only	September	weekend	6709.52	6781.86	6786.83	7345.77	7225.54	8779.26	9704.56	10267.81	10549.67	10587.03	10560.03	10247.82	10297.08	10372.84	10344.88	10348.58	10322.05	8671
34	electricity-only	October	weekend	6172.15	6112.32	5934.85	6440.88	6433.36	8005.37	8817.62	9238.89	9694.3	10007.91	10223.17	10309	10391.52	10311.15	10348.84	10399.14	10364.95	8991
35	electricity-only	November	weekend	6163.84	6111.91	6065.94	6640.16	6716.27	8274.33	9427.64	9385.15	9874.21	10062.15	10065.37	10099	10543.52	10608.37	10603.01	10626.79	10614.23	8972
36	electricity-only	December	weekend	4763.87	4763.91	4769.6	4796.87	5185.87	6376.04	6880.18	7663.87	8315.06	8516.87	8704.96	8891.96	9198.79	9148.88	9176.46	9191.79	9191.79	8196

Modeling in DER-CAM

Sample Case (Cont.) - Tariffs



Entergy Large Commercial Tariff

ENTERGY MISSISSIPPI, INC

Date Filed: December 30, 2014
Date to be Effective: January 30, 2015
Docket No.: 2014-UN-132

MISSISSIPPI PUBLIC SERVICE COMMISSION

P.S.C. Schedule No. I-14
Revised Schedule No. 14, Date: January 30, 2015
Superseded Schedule No. 14, Date: December 31, 2002
Schedule Consists of: Three Pages

LARGE GENERAL SERVICE RATE SCHEDULE C-28

NET MONTHLY RATE

A. RATE

\$4,715.18	for the first 1,000 kW or less of Customer's Demand
\$ 4.644	per kW for all additional kW of Customer's Demand
\$ 0.056330	per kWh for the first 435,000 kWh
\$ 0.053071	per kWh for additional kWh up to 400 kWh per kW of Customer's Demand
\$ 0.050679	per kWh for the next 350,000 kWh
\$ 0.047538	per kWh for all additional kWh
\$ 0.47	per KVAR of Excess KVAR

V. CUSTOMER'S DEMAND

The average kW supplied during the fifteen-minute period of Customer's greatest use in the Day Hours (Day Load) of the current month plus 25% (for Primary Service) or 33 1/3% (in all other cases) of the amount by which the average kW supplied during the fifteen-minute period of Customer's greatest use in the Night Hours (Night Load) of the current month exceeds the Day Load, but not less than the highest of the following:

- (1) 80% of the highest kW so established in the prior eleven months, or
- (2) the minimum kW provided in the Agreement for Service, or
- (3) 1,000 kW.

If the instantaneous load exceeds the highest average fifteen-minute load by an unusual amount, such instantaneous load may be taken as the demand used for billing.

DAY HOURS

Initially 7 a.m. to 9 p.m. C.S.T. (8 a.m. to 10 p.m. C.D.T.) Monday – Friday except holidays. These hours are subject to change by the Company upon thirty days' written notice, but shall not exceed fourteen hours per day.

NIGHT HOURS

All hours not designated as day hours.

Data Processing

- Electricity Rates
 - List of Hours
 - Electricity Charges
 - Electricity Rates
 - Power Demand Charges
 - Daily Demand Rates
 - Monthly Demand Rates
 - Coincident Hour

Electricity Rates					Coincident Hour		
	F1	On	Mid	Off	F1	F2	
1	January	0	0	0.063	1	January	18
2	February	0	0	0.063	2	February	18
3	March	0	0	0.063	3	March	18
4	April	0	0	0.063	4	April	18
5	May	0	0	0.063	5	May	18
6	June	0	0	0.063	6	June	18
7	July	0	0	0.063	7	July	18
8	August	0	0	0.063	8	August	18
9	September	0	0	0.063	9	September	18
10	October	0	0	0.063	10	October	18
11	November	0	0	0.063	11	November	18
12	December	0	0	0.063	12	December	18

Daily Demand Rates						
	F1	coincident	noncoincident	onpeak	midpeak	offpeak
1	January	0	0	0	0	0
2	February	0	0	0	0	0
3	March	0	0	0	0	0
4	April	0	0	0	0	0
5	May	0	0	0	0	0
6	June	0	0	0	0	0
7	July	0	0	0	0	0
8	August	0	0	0	0	0
9	September	0	0	0	0	0
10	October	0	0	0	0	0
11	November	0	0	0	0	0
12	December	0	0	0	0	0

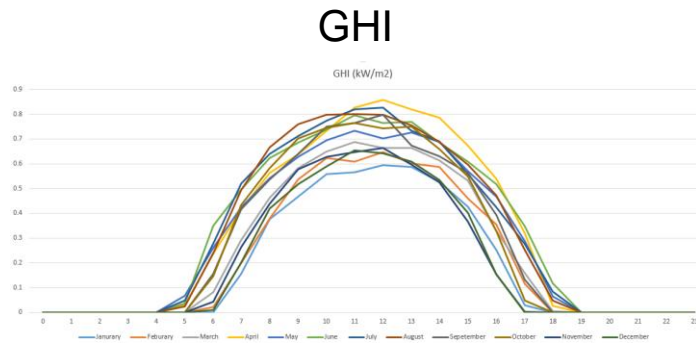
Modeling in DER-CAM

Sample Case (Cont.) – Site conditions

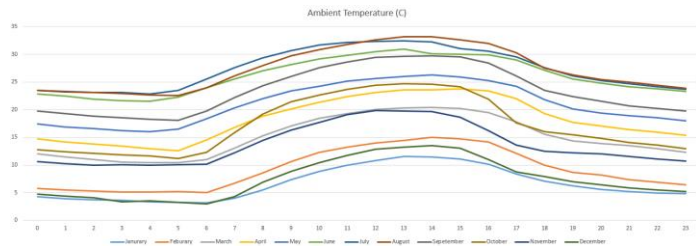
PVWatts

Location and Station Identification

Requested Location	University in Jackson, Mississippi
Weather Data Source	(TMY3) JACKSON INTERNATIONAL AP, MS 5.2 mi
Latitude	32.32° N
Longitude	90.08° W



Ambient Temperature



Data Processing

Solar Insolation

month

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

1 January

0

0

0

0

0

0

0.0051

0.0675

0.2036

0.3174

0.3599

0.3447

0.2932

0.2417

0.1397

0.0466

0.0022

0

0

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0

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0

0

2 February

0

0

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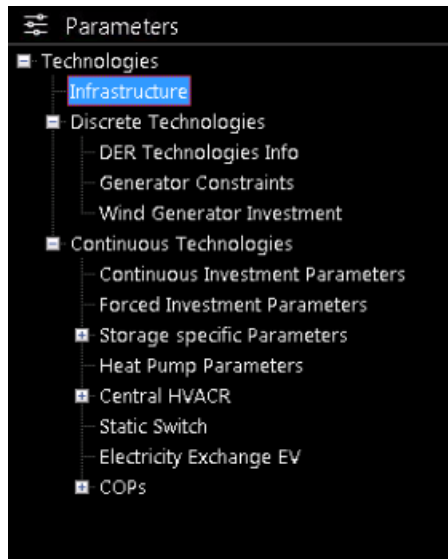
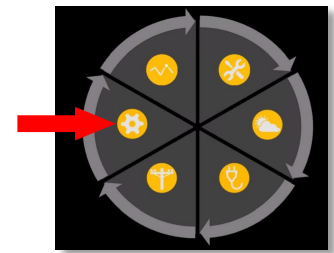
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Modeling in DER-CAM

Sample Case (Cont.) - DER



- Existing
- New
- Force

Renewable Gen

- Solar Photovoltaics

Microturbine

- Max Power (kW)
- Sprint capacity (% of power)
- # of sprint hours (hours)
- Fuel type
- Efficiency (ratio)
- CHP capable? (yes/no)
- Alpha (power to heat ratio)
- NOx emissions rate (kg/hr)
- Maximum annual operating hours (hours)
- Minimum loading (% of power)

- Capital cost (\$)
- Lifetime (years)
- O&M fixed costs (\$/year)
- O&M variable costs (\$/year/unit)
- NOx treatment costs (\$/kg)

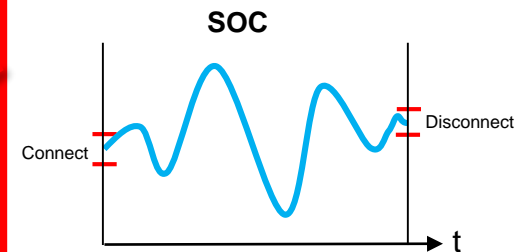
Fossil Fuel Gen

Solar Photovoltaics

- Module rating (kW DC)
- Module Size (m²)
- Efficiency (%)
- Inverter size (kW)
- Total land area (m²)
- Capital cost (\$/kW)
- Lifetime (years)
- O&M fixed cost (\$/year)
- O&M variable cost (\$/year/kW)

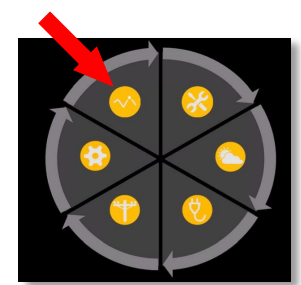
Electric Vehicles

- Multiple locations
- Min connect/disconnect SOC
- Max charge hours
- Battery size
- Efficiency
- Decay
- etc.

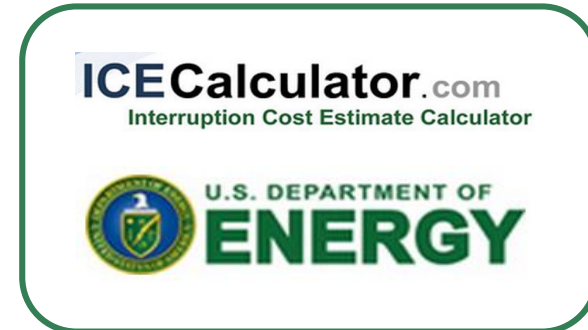
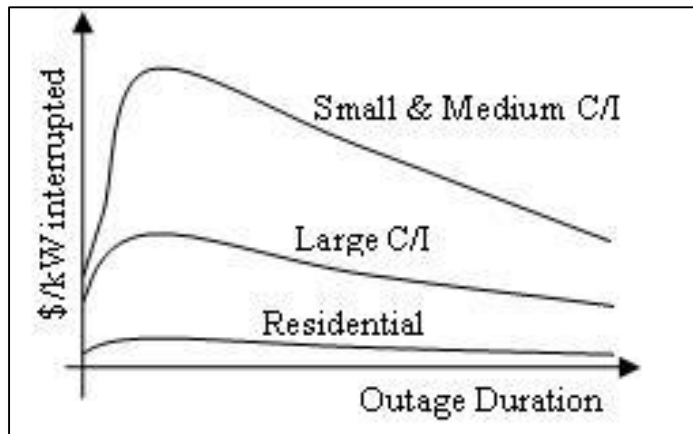


Modeling in DER-CAM

Sample Case (Cont.) - Scenario



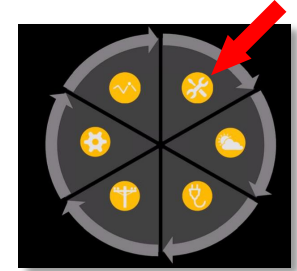
- Outage duration, time
- Value of Loss Load = \$ per kwh not served
 - Customer, time dependent



- Customer preferences
 - How much load can be shifted, within what period
 - How much load can be curtailed, at what price
 - How much load can be curtailed, under an emergency (non-critical)

Modeling in DER-CAM

Sample Case (Cont.) - Parameters



Parameters Table

	F1	F2
1	IntRate	0.05
2	Standby	0
3	Control	0
4	turnvar	0
5	CO2Tax	0.272727
6	macroeff	0.34
7	cooleff	0
8	BaseCaseCost	50000000
9	BaseCaseCO2	50000000
10	MaxPaybackPeriod	10
11	FractionBaseLoad	0.5
12	FractionPeakLoad	0.1
13	ReliabilityDER	0.9
14	MaxSpaceAvailablePVSolar	1620000
15	PeakPVEfficiency	0.1529
16	MultiObjectiveMaxCosts	9000000
17	MultiObjectiveMaxCO2	4400000
18	MultiObjectiveW/Costs	0.6
19	MultiObjectiveW/CO2	0.4
20	ZNEBsolarAreaMultiplier	200
21	ZNEBCostsMultiplier	2
22	BldgShellLifetime	20
23	MinAnnDERGen	0
24	MinAnnRENGen	0
25	MaxAnnDERGen	100
26	MaxExportkW	10000

Options Table

	F1	F2
1	DiscreteInvest	1
2	ContinuousInvest	0
3	DFChillInvest	0
4	WindInvest	0
5	SwitchInvest	0
6	NonPVSales	0
7	PVSales	0
8	NetMetering	0
9	InvestmentConst	0
10	StandbyOpt	0
11	VaryPrice	0
12	DisableCHP	0
13	CO2Tax	0
14	MinimizeCO2	0
15	ZNEB	0
16	MultiObjective	0
17	DiscreteElecStorage	0
18	LS	0
19	CentralHVACR	0
20	CentralHVACRInvest	0
21	GSHPAnnualBalance	0
22	FuelCellConstraint	0
23	BuildingWallInvest	0
24	BuildingWindowInvest	0
25	BuildingDoorInvest	0
26	BuildingRoofInvest	0
27	BuildingGroundInvest	0

interest rate

cap cost/emission

multi-objective cost/emission

renewable penetration

net metering

CO2 Tax

ZNEB constraint

EnergyPlus building retrofit

net metering

CO2 Tax

ZNEB constraint

EnergyPlus building retrofit

Modeling in DER-CAM

Sample Case (Cont.) - Steps

1. Create base case w/ outage

- Assets: Grid, HVAC, boiler, diesel (backup)
- Enable curtailment during outage
- Calculate total value of loss load

2. Obtain base case cost & emissions

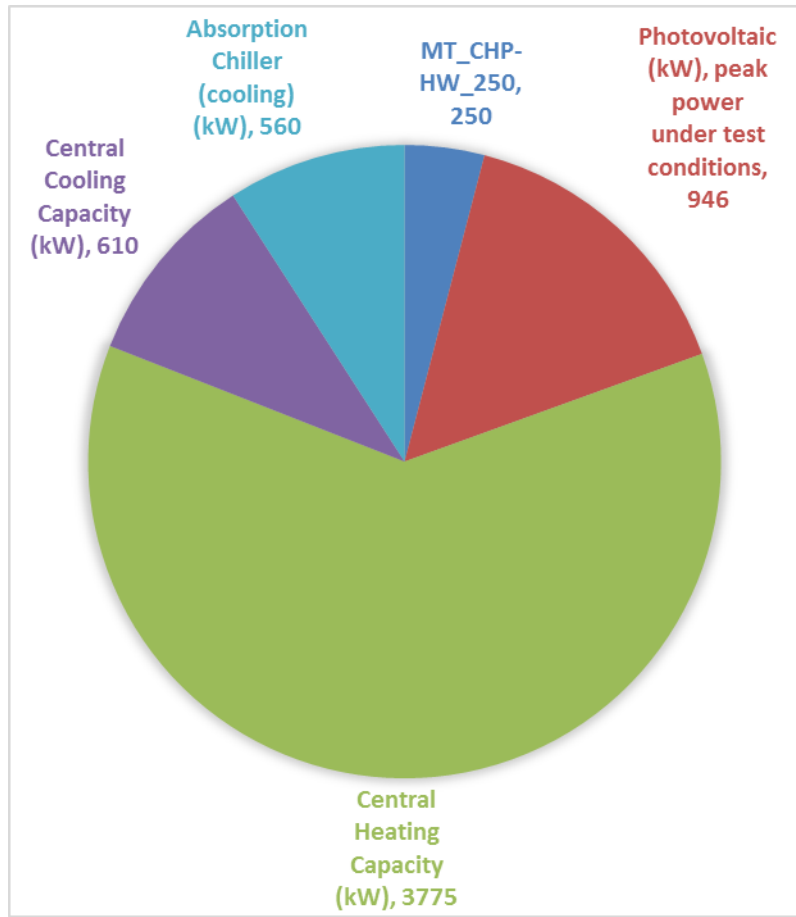
3. Create investment case w/ outage

- Possible new assets: Grid, PV, electric storage, gensets, microturbines, fuel cells, CHP, and absorption chillers.
- Use base cost & emissions as cap
- No curtailment

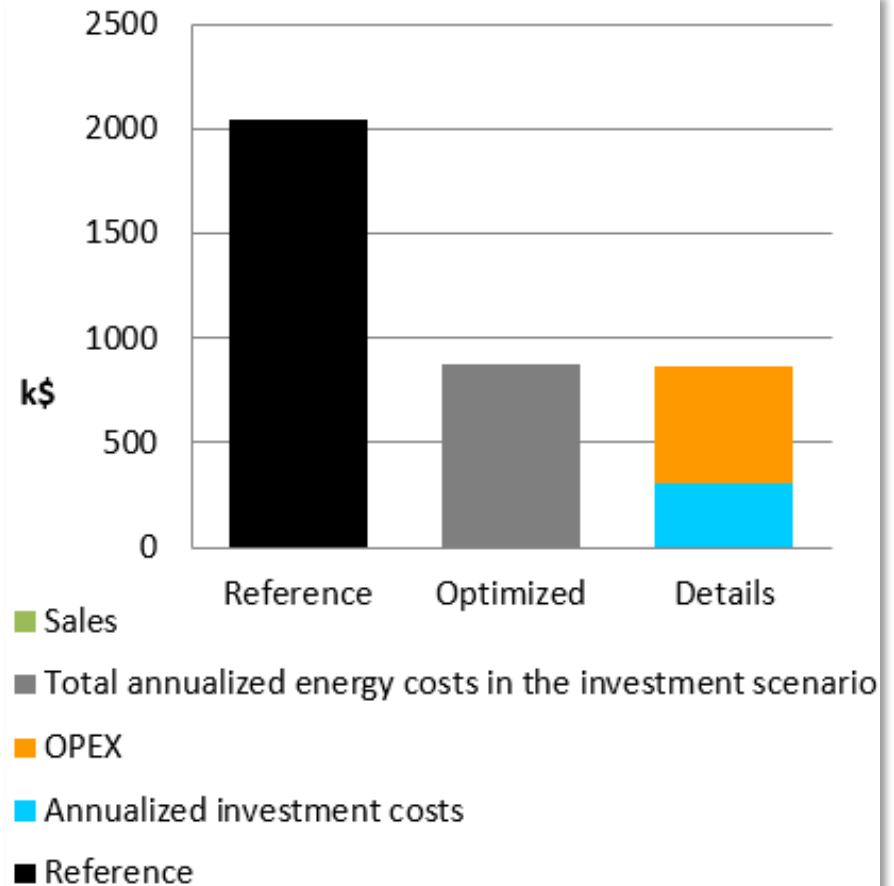
Modeling in DER-CAM

Sample Case (Cont.) - Results

DER Investments (kW)



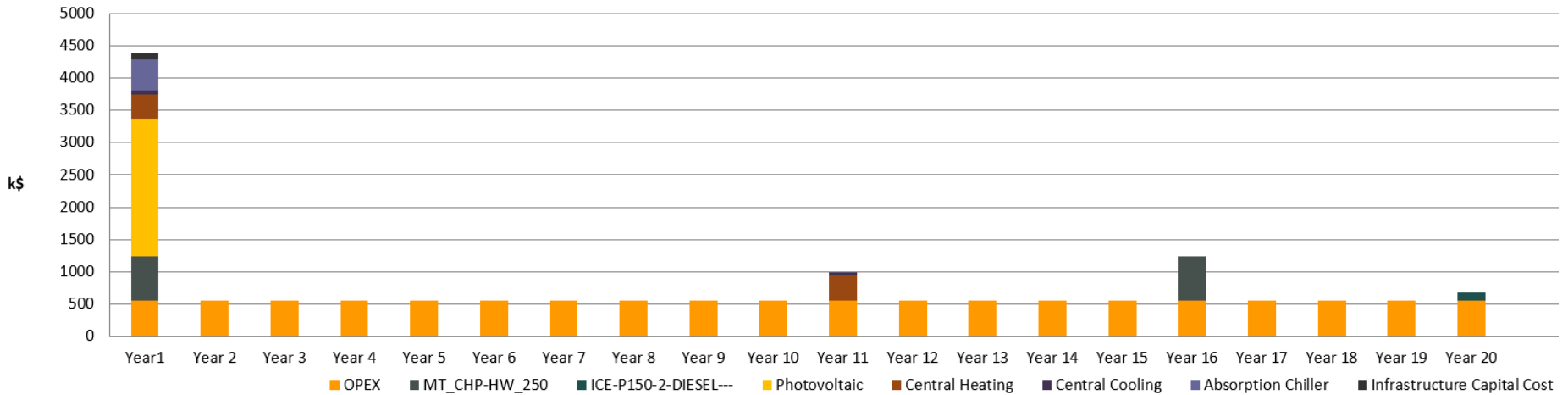
Annualized Cost (k\$)



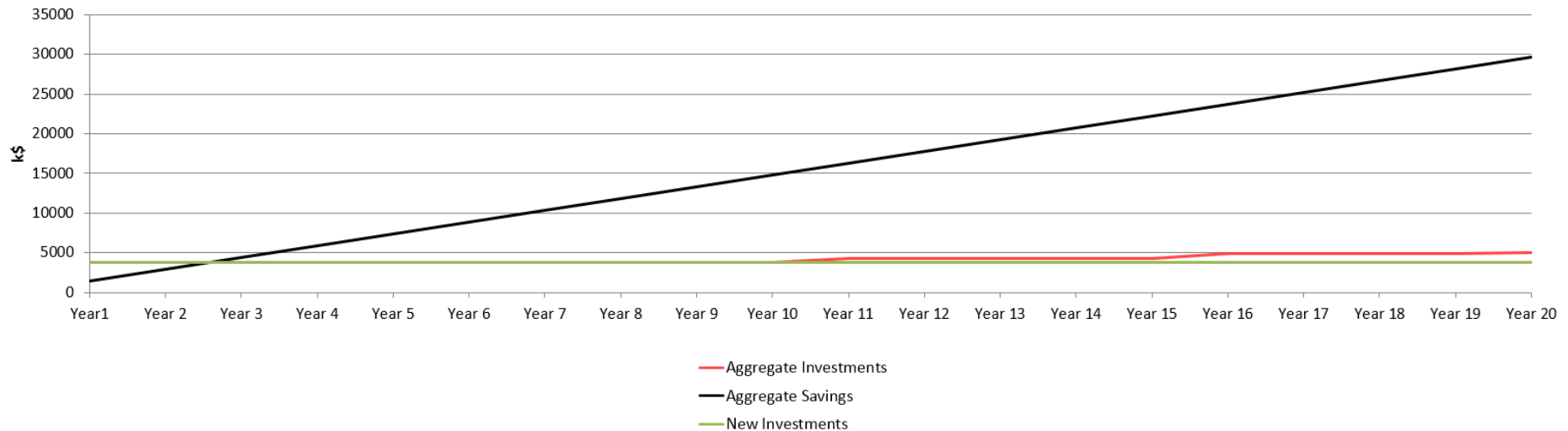
Modeling in DER-CAM

Sample Case (Cont.) - Results

Yearly investments and operational costs (k\$)



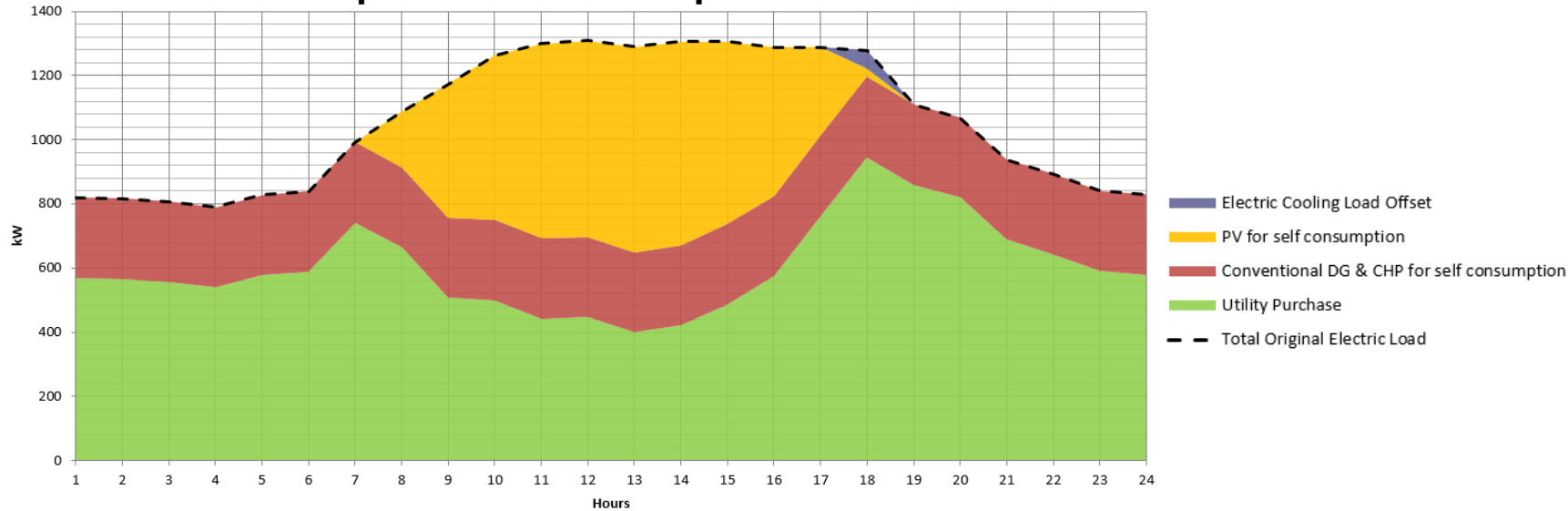
Yearly Investments and Savings



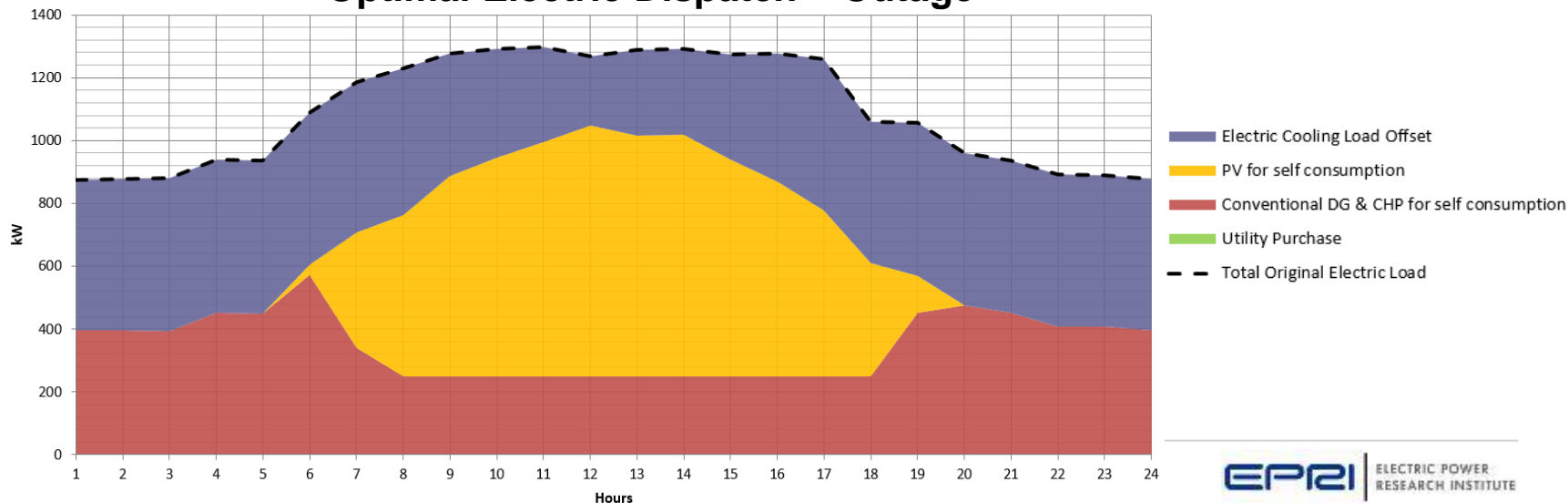
Modeling in DER-CAM

Sample Case (Cont.) - Results

Optimal Electric Dispatch – Normal



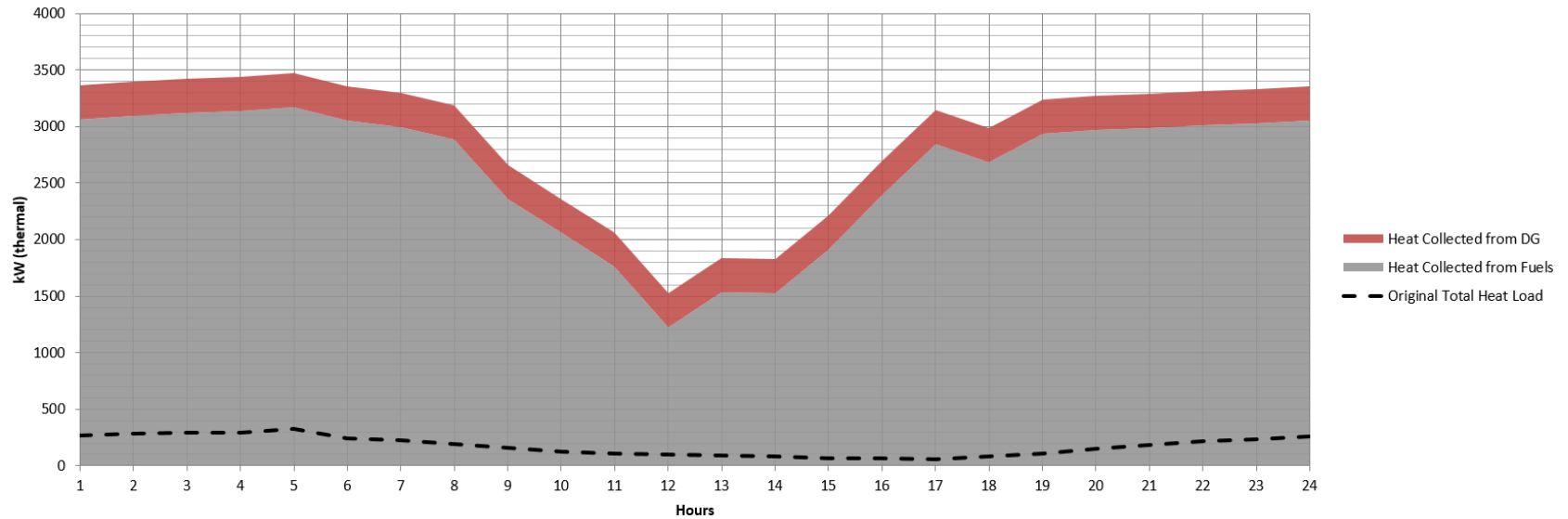
Optimal Electric Dispatch – Outage



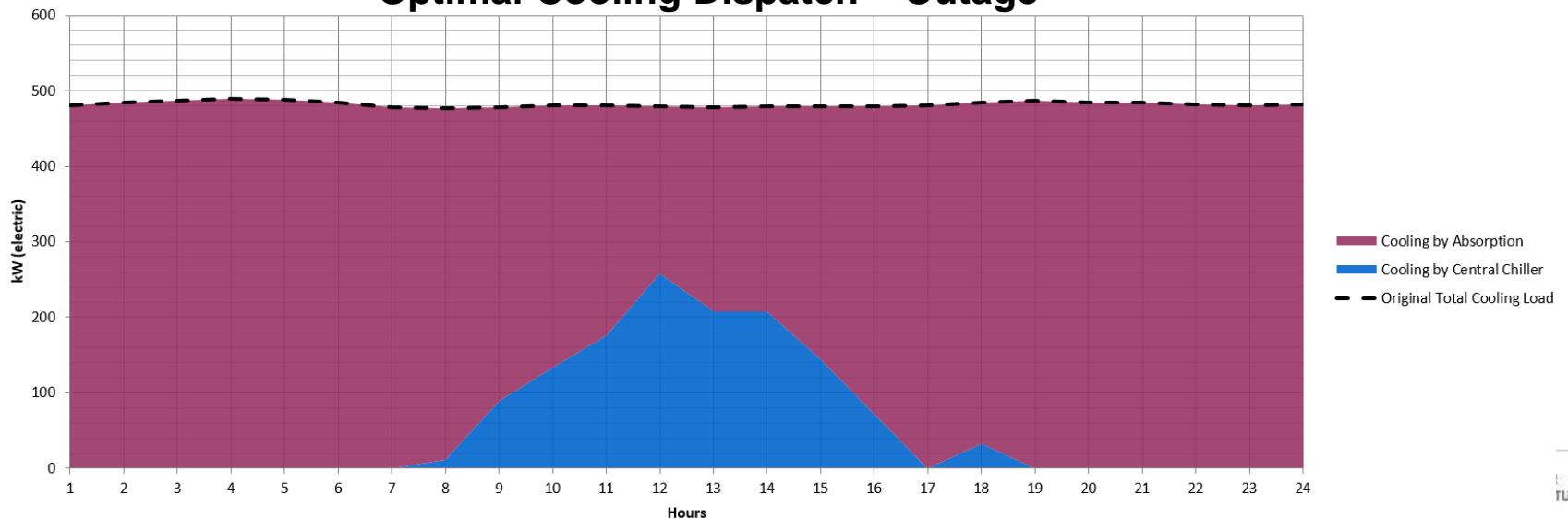
Modeling in DER-CAM

Sample Case (Cont.) - Results

Optimal Heating Dispatch – Outage



Optimal Cooling Dispatch – Outage



EPRI & LBNL Collaboration

- Beta Testing
- Real-world modeling needs
- Projects

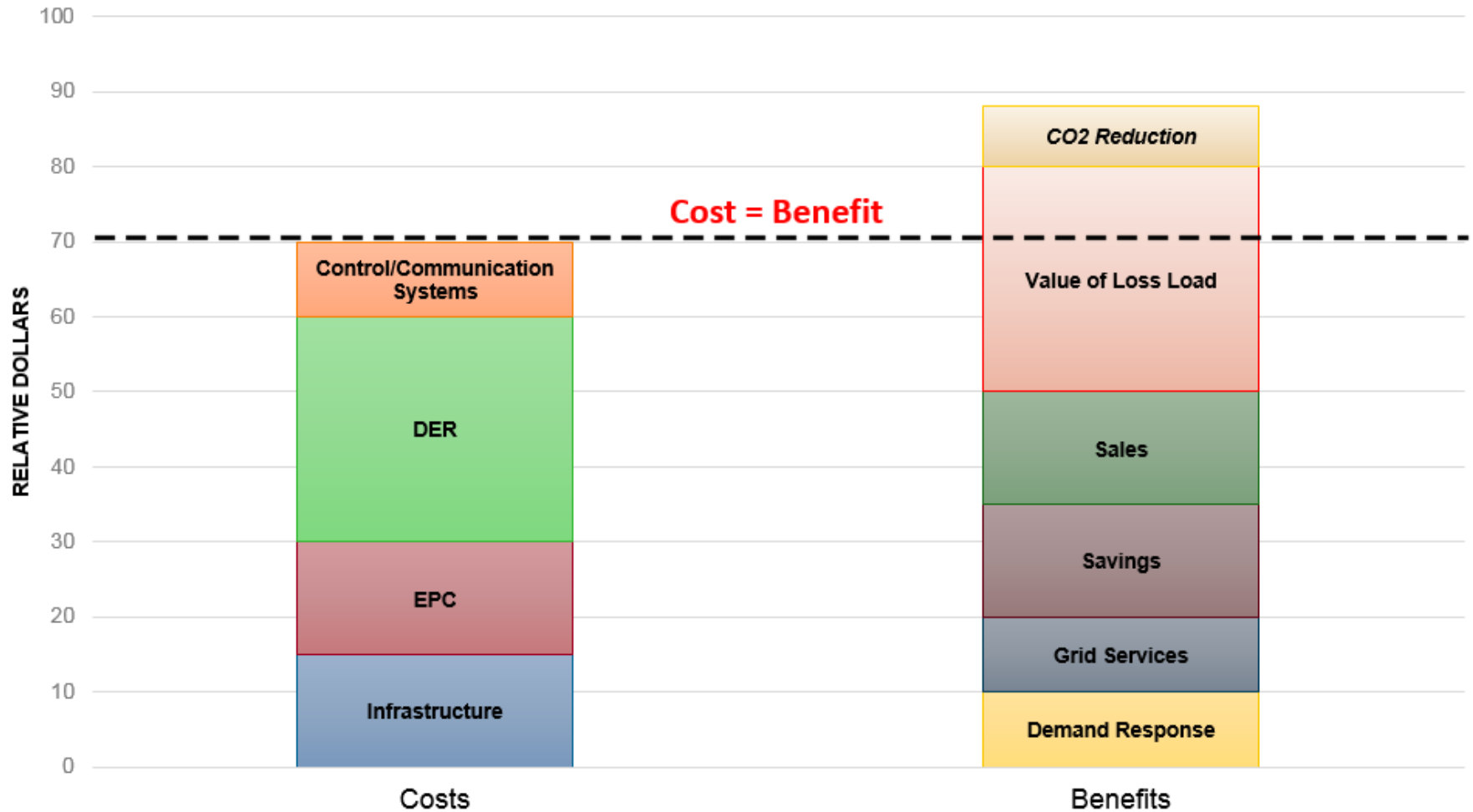


- Training
- Debugging
- Features implementation

New & Upcoming Features

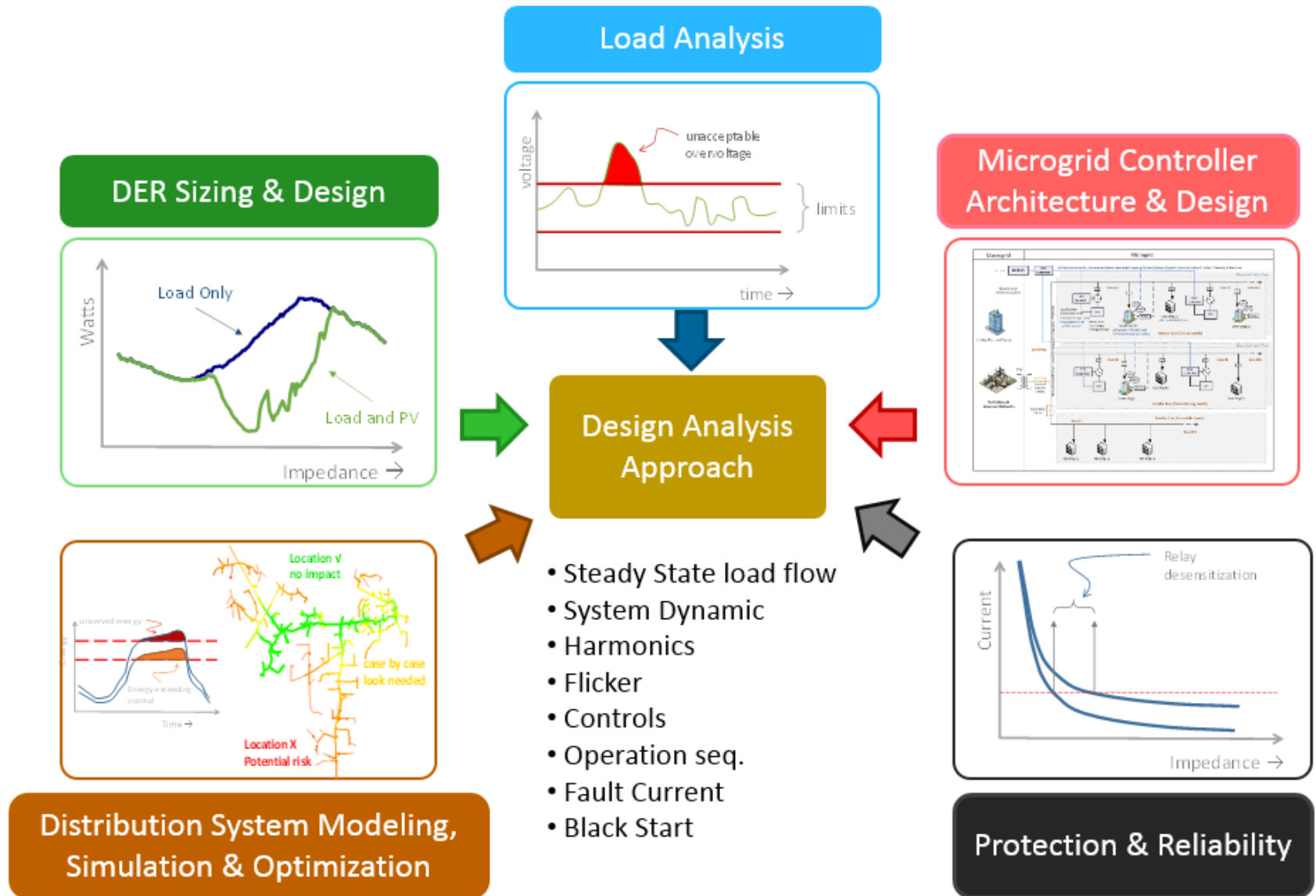
- Nodal network modeling
- 15-min time steps
- Operating reserve
- Demand response
- Thermal load shifting incl. pre-heating/cooling

Cost-Benefit Analysis



An Illustration

Phase II: Detailed Design...



Questions & Comments



- Dean Weng, Project Engineer
865.218.8195, dweng@epri.com
- Arindam Maitra, Technical Executive
704.595.2646, amaitra@epri.com



Together...Shaping the Future of Electricity

Appendix

EPRI Microgrid Project Portfolio

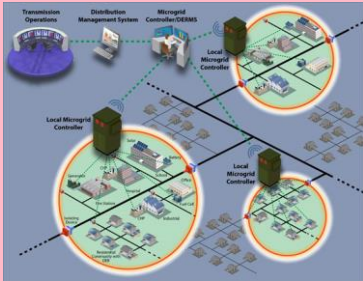
DOE Funded

Microgrid Controller

- R&D
- Vendor Partnership
- Lab Testing, Field Trial

Communications

- Microgrid Controller and DERMS requirements
- Architecture



Utility Collaboration

Feasibility Study

- Host Community
- BCA

Detailed Design

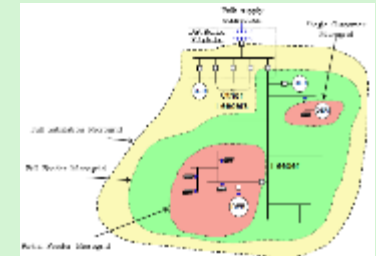
- Host Community
- Modeling

Technical Specification and Guide



Integrated Grid Pilot

- Field Trials
- Demo
- Performance Evaluation
- BCA analysis
- Integration Guides
- Communications, Cyber Security & Privacy
- Utility Level Engagement



Base R&D